Smart Grids for Aquifer Thermal Energy Storage (ATES):
A case study for the Amsterdam Zuidas district

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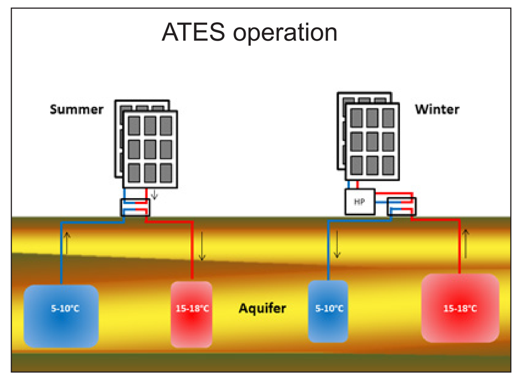
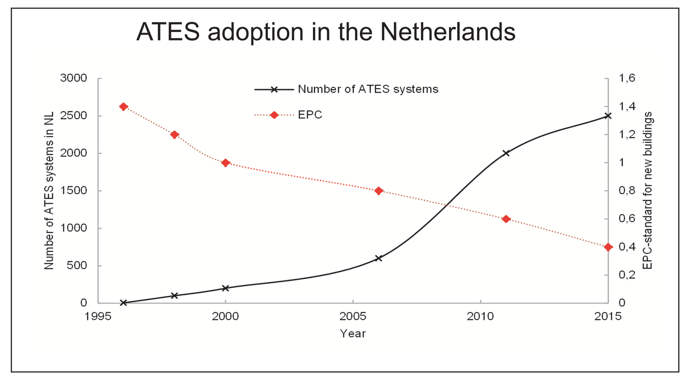
1. Background

This work is part of a project on ATES Smart Grids at TU Delft, which aims to evaluate advanced control systems (e.g. Distributed Model Predictive Control) in improving the performance of ATES systems. The poster presents first results from a case study of ATES development in the Zuidas district of Amsterdam, which will be used to compare different ATES control options and planning policies, and their impact on ATES adoption and aquifer conditions in the area.





2. Research problem

- The Amsterdam Zuidas area has significant potential for future ATES use due to local energy demand, aquifer conditions and available subsurface space
- However, taking advantage of this potential may require changes in current practices for spatial planning and operation

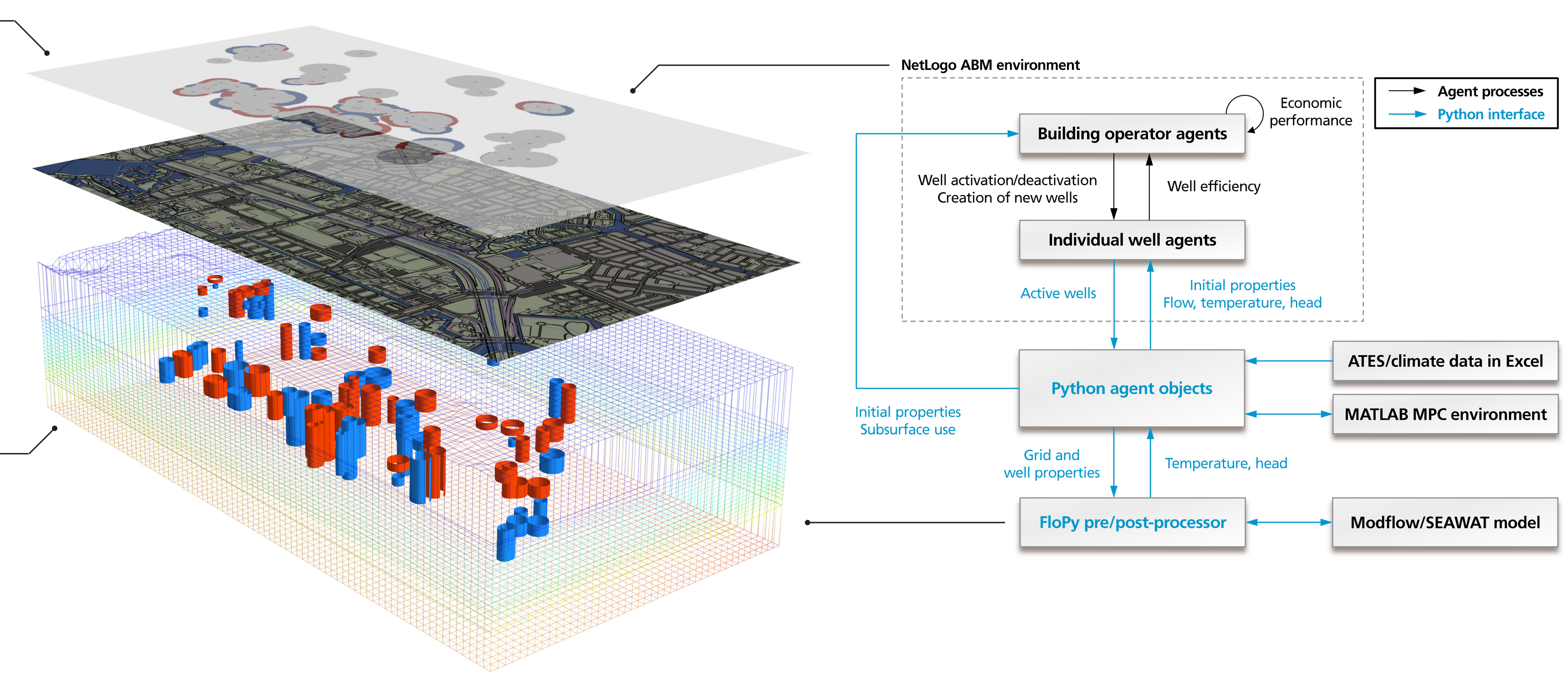
How to maximize the potential of Aquifer Thermal Energy Storage for future development in the Amsterdam Zuidas area?

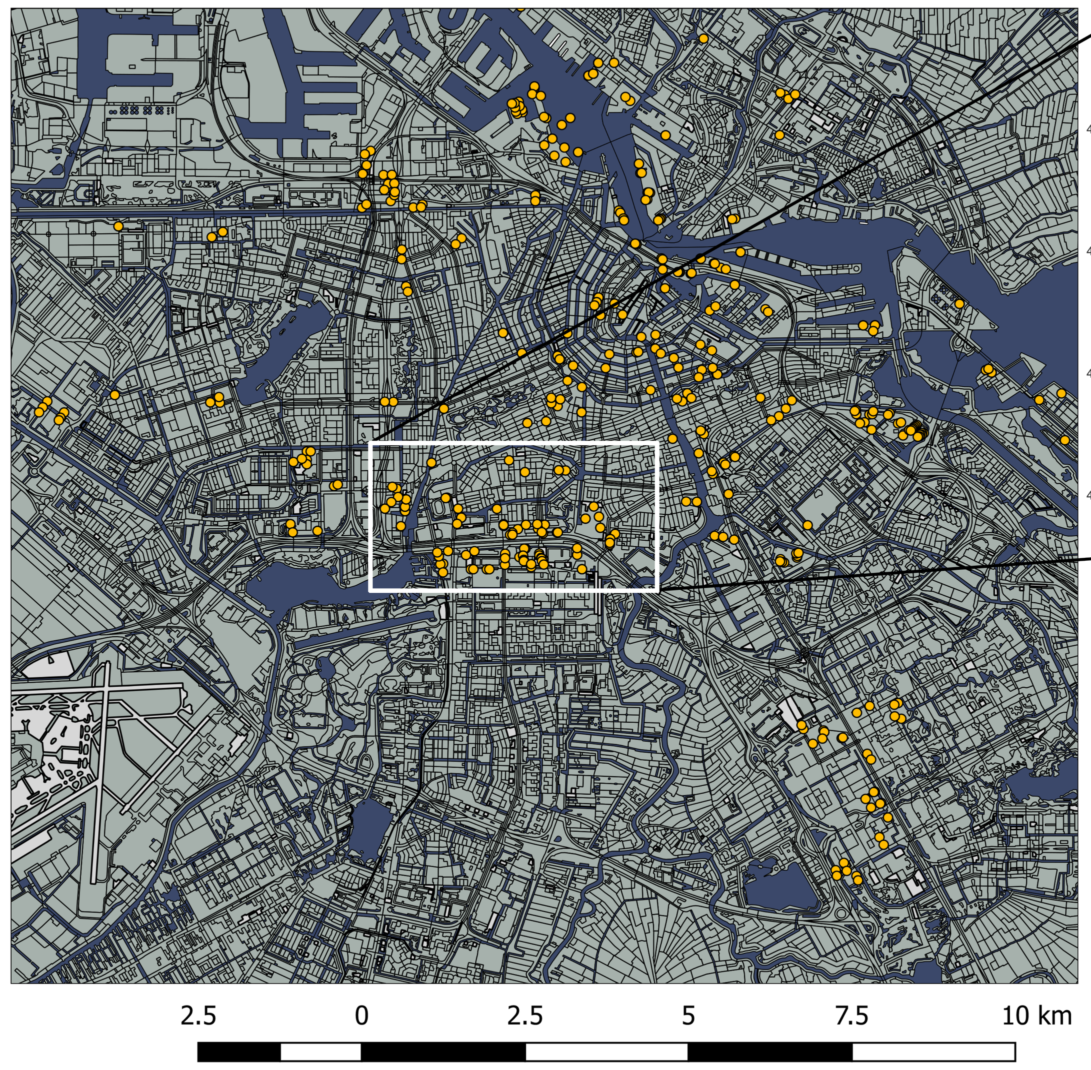
3. Model setup

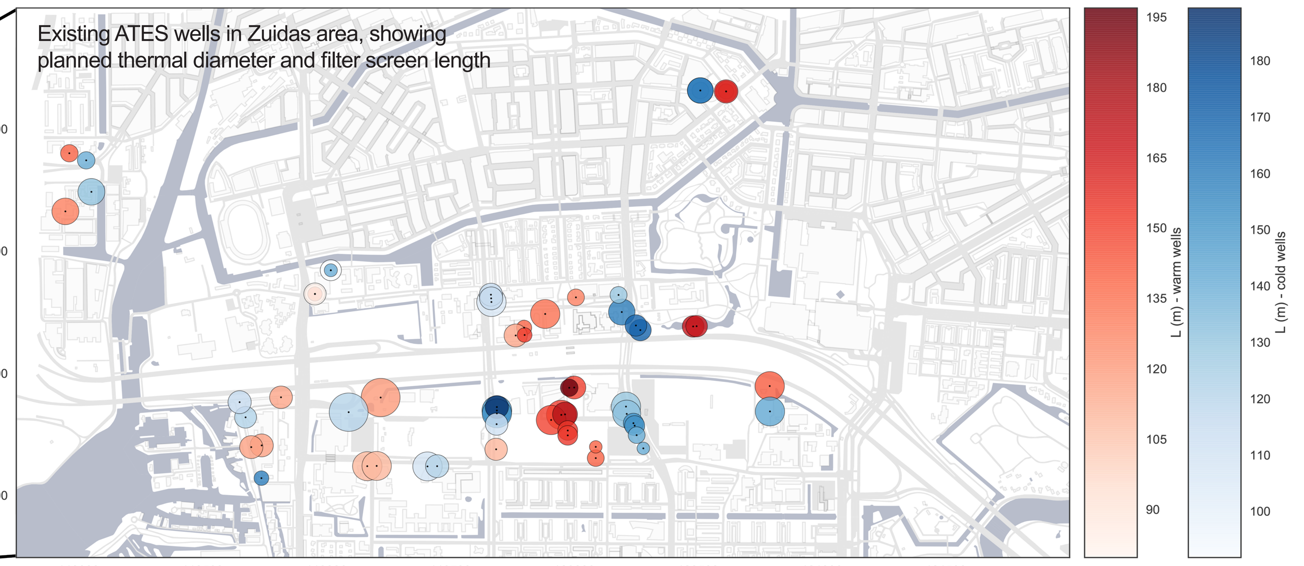
Python interface between a geohydrological model (Modflow/SEAWAT) and an agent-based+GIS ATES operation model (NetLogo)

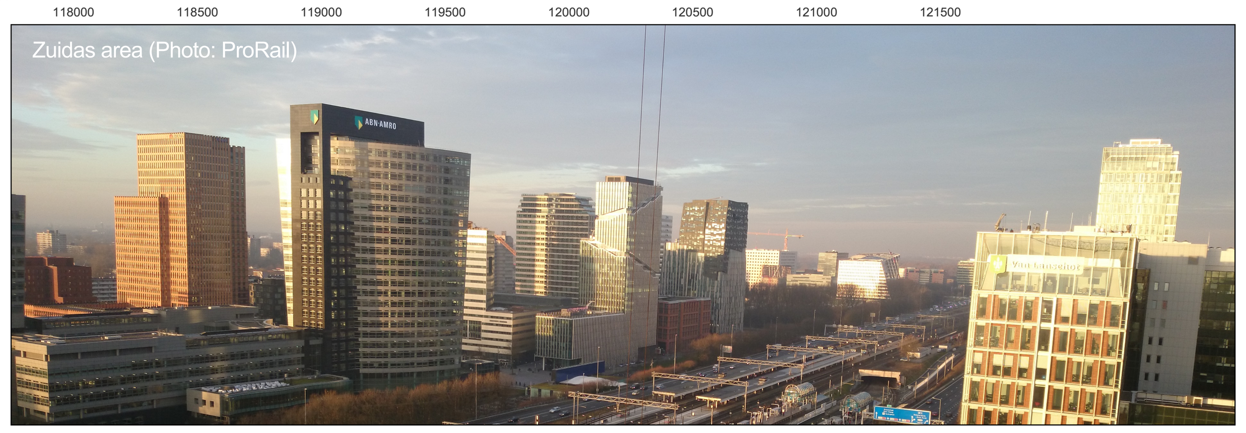
- 4500 x 2500m area around Amsterdam Zuid train station
- Data on 108 existing ATES wells
- Simulated new ATES wells built in available area, based on well layout parameters and surface constraints
- Offline calculation of ATES flows with model predictive control
- GIS data for local land use

- Existing MODFLOW model for regional aquifer conditions
- MT3DMS / SEAWAT for temperature and salinity effects
- Variable grid discretization (5m-20m)
- Monthly time steps over 10 years









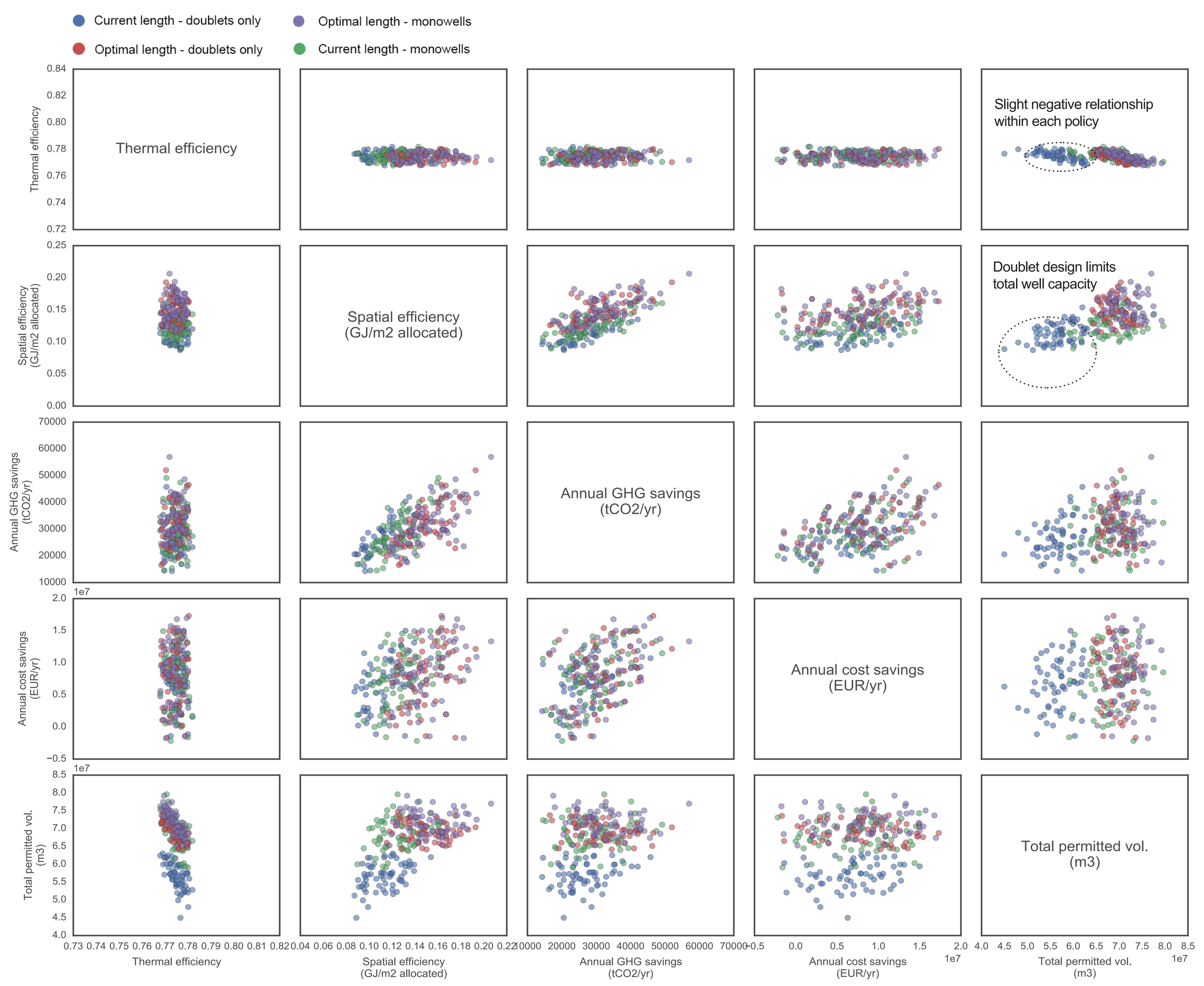
4. Results

The models are simulated across a total of 256 experiments, using a Latin Hypercube sample from the uncertain parameters below. The minimum distance between new simulated wells is based on the expected thermal radius of the wells, assuming operators use their full pumping capacity and maintain thermal balance.

5 main indicators on aggregate values after 120 months for all simulated wells:

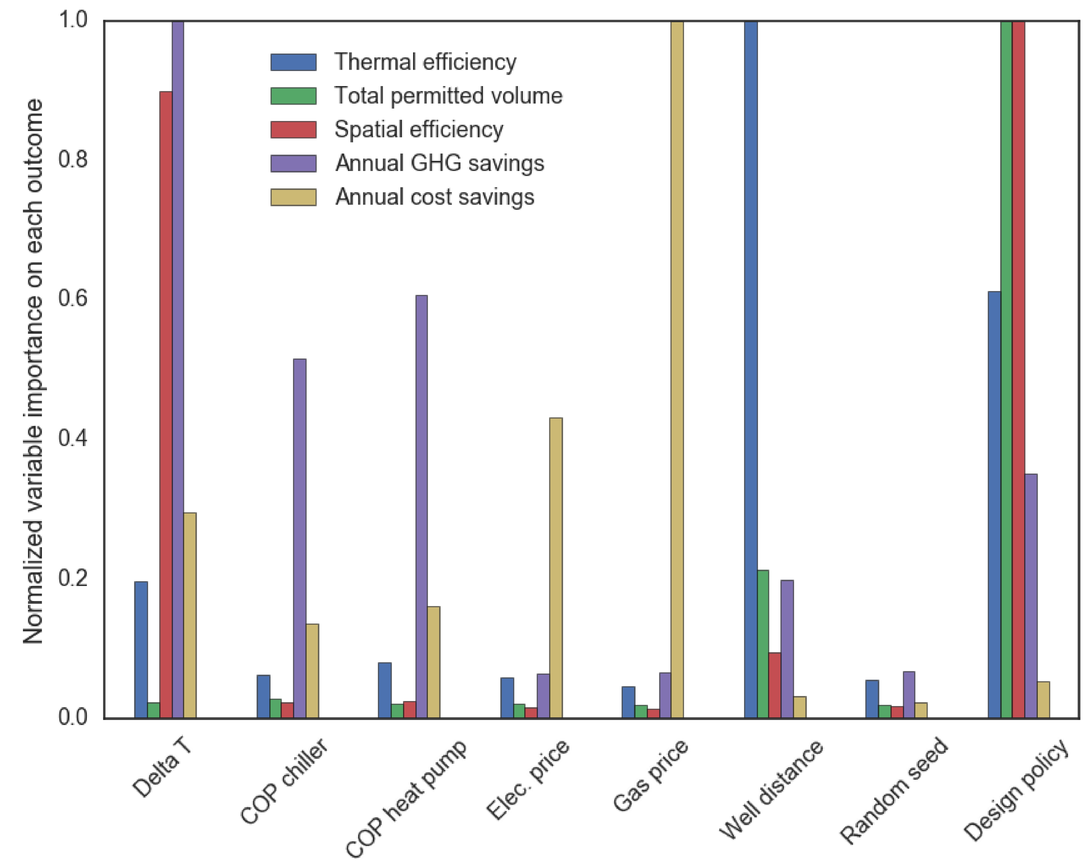
- Average seasonal ATES thermal recovery efficiency
- Total permitted ATES capacity (m^3/yr)
- Spatial efficiency (GJ recovered/m^2 reserved for ATES)
- Average annual GHG savings (tCO_2/yr)
- Average annual cost savings (EUR/yr)

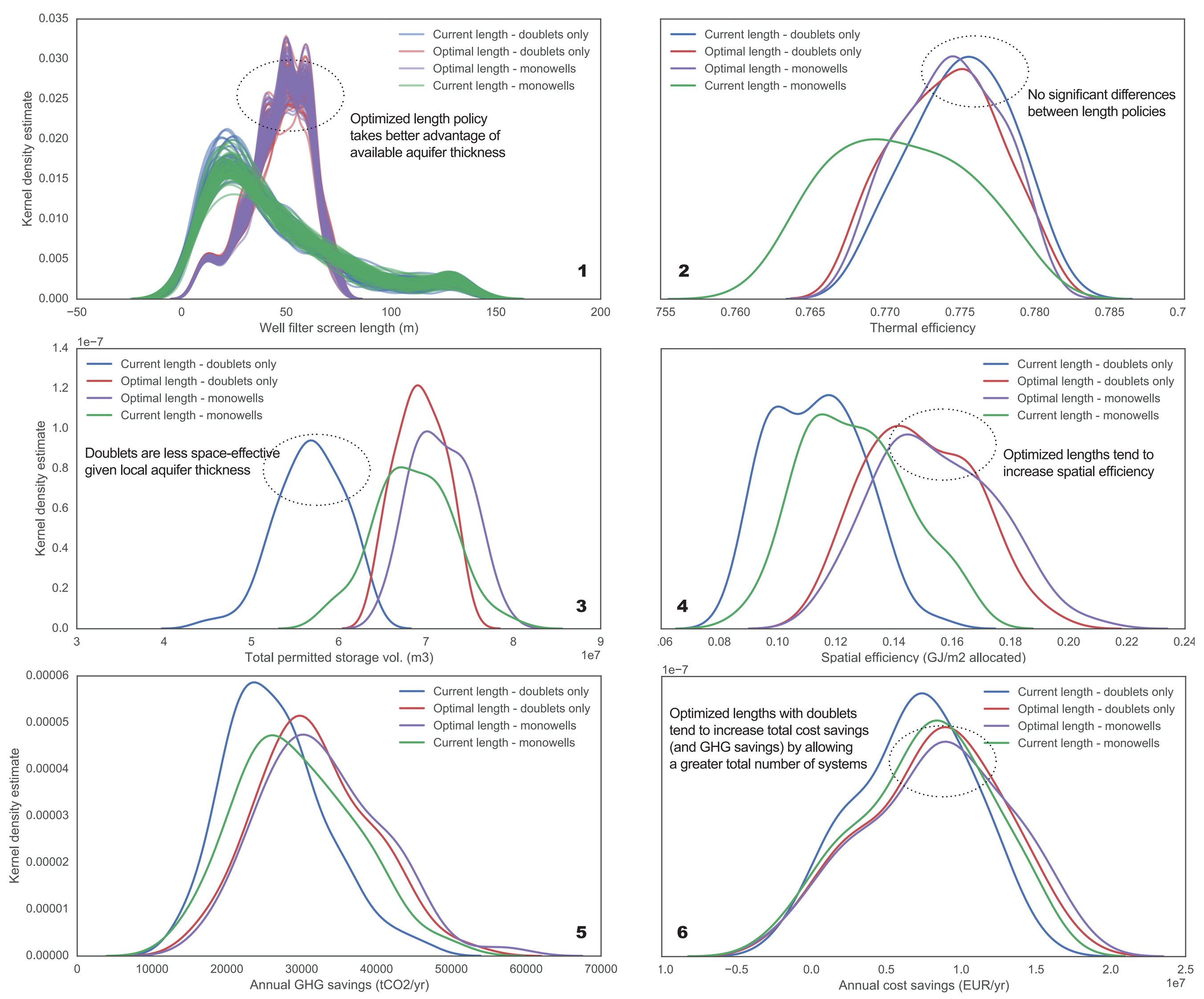
Design policy parameters for simulated new wells		
Well filter screen length	Statistical distribution derived from current practice (Bloemendal & Hartog, 2016), or optimized $V^{1/3}$ relation (Doughty, 1982)	
Type of wells	Mix of doublets or monowells, or doublets only	
Uncertain parameters	**Value or range**	**Unit**
ATES nominal ΔT	4 – 8	[K]
COP chiller	3 – 5	[-]
COP heat pump	3 – 5	[-]
Price for electricity	15 – 60	[€/GJ]
Price for natural gas	5 – 25	[€/GJ]
Distance multiplier between wells	2.5 – 3	[Thermal radius]
Capacity of new wells	30 000 – 300 000	[m^3/yr]



Sensitivity analysis

- Random Forests (Breiman, 2001) are used to approximate a global sensitivity analysis on the key indicators
- The well design policies (filter screen length and well type) have a consistent impact on outcomes. For each outcome, plots 2-6 on the right show the distribution of results, grouped by these policies. Plot 1 additionally shows the distribution of well screen lengths and capacities in each scenario.





5. Conclusions and next steps

- The development of the Amsterdam Zuidas district gives a window of opportunity for improved ATES design, planning and operation, given the local aquifer potential and demand for space heating/cooling in large buildings
- Improved practices for e.g. well filter screen lengths and spatial layout could help maximize this potential, by using the available subsurface space more efficiently
- The ATES flows assumed in the model were based on decoupled (individual) system operation. Further work will account for centralized operation (Rostampour et al., 2016) to better manage thermal interactions and imbalance under operational uncertainties